Ciências da Terra (UNL)	Lisboa	Nº 12	pp. 83-89 3 figs.	1993

Biogeographic and palaeoclimatic relationships of the Middle Pliocene ichthyofauna of the Samoggia Torrent (Bologna, Italy)*

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ABSTRACT

Key words: Middle Pliocene; Ichthyofauna; Biogeography; Paleoclimatology; Bologna; Italy.

New Middle Pliocene ichthyofauna (2.4-2.2 Ma) from central-eastern Italy (Samoggia Torrent, Bologna) are described. These ichthyolites were found in a rather thin laminated layer that was deposited after the 2.4 Ma climatic crisis.

The origin of this deposit, in which 31 taxa have been classified, is to be related to anoxic events on a regional and, probably, supra-regional scale.

This ichthyofaunistic association, which consists of living genera, is characterized by a clearcut predominance of mesopelagic species. The palaeoclimatic characters of these ichthyofauna indicate subtropical-type waters, while from a palaeobiogeographic point of view there is a close relationship with the present-day Atlantic-Mediterranean bioprovince.

The Samoggia deposit has yielded six taxa that are absent or only occasionally present in the Mediterranean; one of these, *Spratelloides gracilis*, is exclusive of the Indo-Pacific bioprovince.

INTRODUCTION

The purpose of this paper is to present the ichthyofauna recently brought to light in a rich deposit of ichthyolites along the Samoggia Torrent (Bologna).

The erosion in this site exposed a layer about five metres thick consisting mostly of clay sediment rich in micro- and macrofauna and containing five identifiable levels, each of which is characterized by different lithofacies (Roveri *et al.*, 1992).

This fossiliferous level was already known, and Bedini & Landini (1986) had described a small collection of its icthyolites that are now kept in the University of Modena's Palaeontology Institute Museum.

Further campaigns allowed researchers to gather an important collection consisting of about 2,000 specimens; these are now in the G. Cappellini Palaeontology Museum of the University of Bologna.

As was said, the layer was divided into five beds with different lithofacies; the ichthyolites come from level nº3, which is 85 cm thick and is made up of alternating greenish clay with contiguous lamination and masses of greenish-grey clay. The ichthyolites were particularly frequent in the laminated layers of the lower part of this level.

THE AGE OF THE DEPOSIT

This deposit has been dated, by means of micropalaeontological and magnetostratigraphic analysis, at the Middle Pliocene, *Globorotalia* ex gr. *crassaformis* NN18 biozone, lower part of the Matuyama Crona (Roveri *et al.*, 1992), which falls in the interval between 2.48 Ma and 0.8 Ma.

On the basis of the presence and absence of certain ichthyolites whose stratigraphic distribution has been established in other Pliocene deposits in Italy, it is possible to delimit this time interval.

In fact, in the Marecchia River ichthyolite deposit in which 15 layers with fish have been recognised and dated between 2.9 and 2.2 Ma, two taxa —*Centriscus strigatus* and a large Syngnathid — disappeared after the 2.4 Ma climatic crisis (Sorbini, 1988). These two taxa are not in the ichthyofaunistic association in the Samoggia Torrent. As for the upper chronological limit, Landini & Menesini

* - This paper was made possible by a grant from the C.N.R. - Comitato per le Scienze Geologiche e Minerarie, C.T. nº. 9002526.

(1988) have pointed out the absence of *Bregmaceros albyi* in the Mediterranean basin around 2.2 Ma; this species is on the other hand well represented in the Samoggia Torrent association. Therefore, on the basis of these data it is possible to restrict the deposit time span of the ichthyolite layer from 2.4 to 2.2 Ma.

THE SAMOGGIA TORRENT ICHTHYIC ASSOCIATION

The 2,000 specimens examined are for the most part in a good state of preservation. They belong to 21 families, 28 genera and 17 species, to which one should add *Engraulis* sp., *Electrona* sp. and *Sarda* sp., which were classified by Bedini & Landini (1986), thus making a total of 31 genera classified so far in the ichthyofaunistic association.

Systematic list

OSTEICHTHYES

1. Fam. Dussumieriidae
   Etrumeus teres (De Kay, 1842)
   Spratelloides gracilis (Schlegel, 1846)
2. Fam. Engraulidae
   Engraulis cf. encrasicholus (Linnaeus, 1758)
3. Fam. Gonostomatidae
   Cyclothone sp.
4. Fam. Sternoptychidae
   Argyropelecus hemygymnus Cocco, 1829
   Maurolicus muelleri (Gmelin, 1788)
   Electrona sp.
7. Fam. Paralepididae
   Lestidiops sp.
8. Fam. Carapidae
   Carapus sp.
9. Fam. Syngnathidae
   Syngnathus acus Linnaeus, 1758
10. Fam. Merlucciidae
    Merluccius merluccius (Linnaeus, 1758)
11. Fam. Gadidae
    Gadiculus sp.
    Micromesistius poutassou (Risso, 1826)
12. Fam. Bregmacerotidae
    Bregmaceros albyi Sauvage, 1880
13. Fam. Caproidae
    Capros aper (Linnaeus, 1758)
14. Fam. Carangigae
    Trachurus sp.
15. Fam. Chaetodontidae
    Chaetodon hoefleri Steindachner, 1881
16. Fam. Trichiuridae
    Lepidopus sp.
17. Fam. Scombridae
    Auxis sp.
    Sarda sp.
    Scomber cf. *calabrensis* Bannikov & Landini, 1981
18. Fam. Xiphiidae
    Xiphias gladius Linnaeus, 1758
19. Fam. Bothidae
    Arnoglossus laterna (Walbaum, 1792)
20. Fam. Soleidae
    Solea sp.
21. Fam. Monacanthidae
    Aluterus sp.
    Cantherhines sp.

THE SAMOGGIA TORRENT ICHTHYOFAUNA AND COEVAL ICHTHYOFAUNA

All the classified genera belong to present day fauna, and among the species, only *Bregmaceros albyi* and *Scomber calabrensis* are extinct. Furthermore, this was the first time that *Chaetodon hoefleri* (Fig. 1), *Auxis*, and *Carapus* (already found as an otolith) have been found in Pliocene deposits in the Mediterranean basin. Since 68 taxa of Lower and Middle Pliocene ichthyofauna in the Mediterranean basin were previously known (Landini & Sorbini, 1992), the total is now 71 taxa.

Like the other Lower and Middle Pliocene ichthyofauna, the great majority of ichthyofauna in this association consists of living species, as the fossil species represent only 10% of the total; this differentiates them quite radically from the ichthyofaunistic associations of the Upper marine Miocene of the Mediterranean, in which the percentage of fossil species is about 90% (Landini & Menesini, 1984).

The modern character of the Samoggia Torrent ichthyofaunistic association thus leads to some considerations of a palaeoecological, palaeoclimatic and palaeobiogeographical nature.

As far as the quantitative relations are concerned, one can point out the predominance of two taxa, *Maurolicus muelleri* and *Bregmaceros albyi*, which by themselves go to make up 70% of the entire collection; they are followed by the Dussumierids and Engraulids (5%), and the Mictophids (also 5%), while there are very few specimens of the remaining taxa.

From an ecological standpoint this association is thus characterized by the clearcut predominance of pelagic species, which go to make up about 90% of the total, while the neritic species are quite reduced in number.

Among the pelagic taxa, the mesopelagic ones (Bregmacerotidae, Gonostomatidae pars and Myctophidae) are by far the most abundant (about 80%), followed by the epipelagic Carangidae, Scombridae, Xiphidae, Dussumieridae, and Engraulidae (7-8%), and the bathypelagic ones, here represented only by the genus *Cyclothone*; the neritic taxa consist of a small benthic group (Bothidae, Soleidae and Ophididae) and another equally small nectobenthic one (Monacanthidae, Syngnathidae, Caproidae, Chaetodontidae), which both represent about 2% of the total specimens.

The high percentage of mesopelagic specimens, in association with a small bathypelagic component, compared to such a small percentage of neritic specimens, suggests deposition along the continental slope.

Though taking into account the nychthemeral movements of most of the mesopelagic taxa, which might have taken them to shelf environments, the presence among these of the genera *Cyclothone*, *Argyropelecus* and *Lampanyctus*,

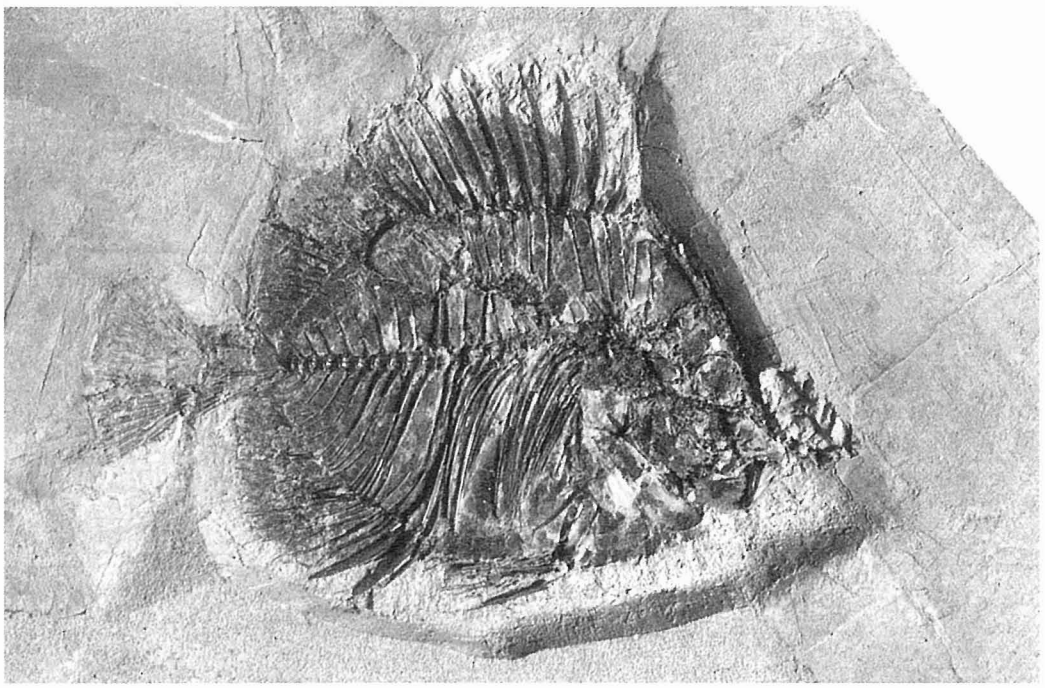

Fig. 1 — *Chaetodon hoefleri* Steindachner. Standart lenght 7,5 cm.

which generally do not go over the 200 m limit, confirms an environment outside the slope margin.

In the fossiliferous deposits formed in the shelf environment the qualitative and quantitative relationships between these components are different and the presence of the mesopelagic taxa, made up only partially of migrants, is generally seen to be due to nychthemeral migration, which allows this particular category of fishes to go up and spread out over the shelf.

Furthermore, the presence, albeit sporadic, of strictly coastal taxa (*Syngnathus, Chaetodon*) is a point in favour of the hypothesis of a close spatial relationship between these environments that occurs in conditions of limited extension of the continental shelf.

Compared to the sites of other Italian deposits containing Lower and Middle Pliocene ichthyolites, the one in the Samoggia Torrent is shallower than the Stuni deposit (Landini & Menesini, 1986) and deeper than the Marecchia river deposit . The greatest affinities seem to be with the Metauro river deposit, in which the different ecological categories have a distribution pattern similar to that in the Samoggia Torrent (Sorbini, 1988).

THE ORIGIN OF THE DEPOSIT

Palaeontological and sedimentological data allow for a hypothesis concerning the origin of this deposit.

The laminated levels contain ichthyofauna in abundance with well preserved and generally intact specimens. As was said above, the benthic taxa are low in number (2%) and consist mostly of young forms of Pleuronectiformes.

By themselves these taxa indicate conditions of only slight oxygenation on the sea floor, which is confirmed by the total disappearance in level no. 3 of benthic mollusks, which are however present in the level immediately underneath, and by the increase in the number of plaktonic mollusks dominated by pteropods as well as by fossil plants in abundance (Roveri *et al.*, 1992).

From a sedimentological point of view the preservation of the laminar structure of the ichthyolite strata indicates the absence of bioturbation which is an indicator of anoxic conditions on the sea floor. As is known, the Middle and Lower Pliocene anoxic beds extend over much of central-eastern Italy, from Bologna province to Macerata Marche (Sorbini, 1988). These strata, which all lie in a short stratigraphic interval, have ichthyofauna with a taxonomic structure, bioecological composition and palaeobiogeographic significance that are quite similar.

This ichthyofauna is usually accompanied by very particular mollusk populations characterized by hardly any, or no benthic taxa. In general the specimens are well preserved, as is shown by the presence of delicate structures (for example, photophores) in certain ichthyolites, the high percentage of organic substances, the presence of plant frustules in abundance in some zones, and lastly, by the preservation of primary sedimentary structures.

Moreover, some of these beds are stratigraphically correlated with layer no. 3 of the Samoggia Torrent: these are fish beds no. 12, 13, and 14 of the Marecchia river site that were deposited after the 2.4 Ma climatic crisis.

All this indicates the existence of anoxic events that are related on a regional scale (central-eastern Italy) and are probably related to other events noted in the same stratigraphic interval in the Mediterranean, as the fish beds at Stuni in southern Italy seem to indicate, among other things.

Etrumeus teres	Coastal pelagic
Spratelloides gracilis	Coastal pelagic
Engraulis	Coastal pelagic, euryhaline, up to 400 m
Cyclothone	Oceanic, meso- or bathypelagic
Argyropelecus hemygymnus	Oceanic, mesopelagic
Maurolicus muelleri	Oceanic, mesopelagic, from 10 to 400 m
Vinciguerria	Oceanic, mesopelagic, from 200 to 800 m, with daily vertical migrations
Ceratoscopelus maderensis	Oceanic, mesopelagic
Diaphus	High-oceanic mesopelagic or pseudoceanic pelagic, epibenthic
Lampanyctus pusillus	Oceanic, meso- and bathypelagic
Lobianchia dofleini	High-oceanic, mesopelagic
Electrona	High-oceanic, mesopelagic
Lestidiops	Epi- and mesopelagic
Syngnathus acus	Coastal and in estuaries up to 90 m, on sandy, muddy bottoms, common among algae and grass beds
Merluccius merluccius	Bathypelagic from 50 to 1000 m
Gadiculus	Bathypelagic from 200 to 1000 m
Micromesistius poutassou	Mesopelagic
Bregmaceros	Neritic and oceanic
Capros aper	Near floors between 40-600 m
Trachurus	Mainly near floors between 20-500 m, also pelagic
Chaetodon hoefleri	Inshore waters, close to bottom, from 20 to 100 m
Lepidopus	Benthopelagic, on the continental shelf up to 400 m
Auxis	Epipelagic in inshore waters
Sarda	Epipelagic, especially in coastal waters
Scomber	Epipelagic
Xiphias gladius	From epipelagic up to 800 m
Carapus	Shallow waters, typically commensal in the holothurians
Arnoglossus laterna	Benthic
Solea	Benthic up to 200 m
Aluterus	Coastal, on floors with algae
Cantherhines	Coastal, on floors with algae

Fig. 2 — Ecological characters of taxa found in the Samoggia Torrent deposit.

PALAEOCLIMATIC CHARACTERS

The palaeoclimatic characters of the Samoggia Torrent ichthyofauna can be seen in fig. 3, which indicates the type of sea now inhabited by the various taxa found in the fossil state.

One notes above all that 27 out of a total of 31 taxa can also live in subtropical waters, and 22 in warm temperate waters, while only two taxa can live in cold water as well. Therefore, from a palaeoclimatic point of view the Samoggia Torrent ichtyofaunistic association fits in quite well with those present day associations living in the warmer areas of the Mediterranean bioprovince.

In fact, the presence of certain taxa such as *Spratelloides gracilis, Aluterus, Cantherhines, Chaetodon hoefleri, Etrumeus teres* and *Bregmaceros*, which live exclusively in tropical or subtropical waters, characterizes this ichthyofauna as subtropical. In fact, because of the presence of taxa such as *Spratelloides* and *Etrumeus*, this ichthyofauna can be compared to that now living in the eastern Mediterranean, where the winter surface temperature never falls below 16 °C and the summer temperature goes up to 30 °C, as well as on the African coasts of the Atlantic, where *Chaetodon, Aluterus, Cantherhines* and *Bregmaceros* live.

The persistence of taxa with subtropical affinities even after the 2.4 Ma climatic crisis corresponds, in fact, to the coeval strata in the Marecchia river deposit, since here too such taxa with subtropical affinities as *Bregmaceros, Sargocentrum, Spratelloides* and *Aluterus* were present after this crisis.

PALAEOBIOGEOGRAPHIC RELATIONSHIPS

As we have seen, the Samoggia Torrent ichthyofaunistic association consists of living genera, whereas on a specific level only two taxa are related to extinct species (*Bregmaceros albyi* and *Scomber calabrensis*). Of the 31 identified genera, 25 live in the Mediterranean, while 6 are absent or only occasionally present. Therefore the most important biogeographic affinities lie with the present day Atlantic-Mediterranean region.

Those genera that are absent or only occasionally present in the Mediterranean are: *Bregmaceros, Chaetodon, Aluterus* and *Cantherhines*, which live along the African coasts of the Atlantic; the genus *Etrumeus*, which lives in the Indo-Pacific and along the American coasts of the Atlantic; and *Spratelloides*, which lives exclusively in the Indo-Pacific region. Altogether, these genera represent 20% of those classified.

It is interesting to note that the genera *Etrumeus* and *Spratelloides* are considered Lessepsian migrators (Por, 1978) and therefore now live in the eastern Mediterranean. The presence in the Samoggia Torrent ichthyofauna of 4 genera that live along the African coasts of the Atlantic bears witness to the fact that during the Middle Pliocene, biogeographic relations with the Mauritanian province were closer than they are at present.

The presence of *Spratelloides gracilis* in the Samoggia deposit poses an interesting problem. This species now lives exclusively in the Indo-Pacific biogeographic region and has never been found as a fossil outside this region, except for the Mediterranean basin, where it was present in the Upper Miocene. The fact that this species was found in the Samoggia deposit thus suggests that during the salinity crisis a marine environment with normal salinity levels may have persisted in the eastern Mediterranean, which would have made it possible for the ichthyofauna of Tethyan origin (which today have exclusively Indo-Pacific affinities) to survive.

Furthermore, besides *Spratelloides gracilis*, the Marecchia river deposit yielded other species with exclusive Indo-Pacific affinities that were already present in the Mediterranean basin during the Upper Miocene: *Centriscus strigatus, Sargocentrum rubrum*, and *Hemiramphus far.* These taxa can be considered Pliocene relicts of Tethyan origin, since their presence in the Mediterranean Pliocene can be set in relation only with the Tethys Sea and with conditions of normal salinity in certain areas of the eastern basin of the Mediterranean during the salinity crisis (Sorbini, 1988).

All this leads to other considerations and calls for further research. *Spratelloides gracilis, Hemiramphus far, Sargocentrum rubrum* and *Etrumeus teres*, whose presence in the Mediterranean has been ascertained up to 2.2 My (that is, after the climatic crisis of 2.4 My), are in fact present today, together with other species with subtropical affinities, in the eastern Mediterranean and are considered Lessepsian migrators (Por, 1978).

However, we cannot rule out the possibility that these taxa with subtropical Indo-Pacific affinities also survived other climatic crises in the Upper Pliocene and the Quaternary. Further research in more recent Pliocene deposits in the eastern zone of the Mediterranean basin may reveal new deposits of species with subtropical Indo-Pacific affinities (Sorbini, 1991).

CONCLUSIONS

The new ichthyofaunistic association of the Samoggia Torrent deposit has allowed us to extend our knowledge of the Pliocene populations in the Mediterranean, thus revealing the presence of certain taxa that have not been found in other deposits — *Chaetodon hoefleri, Auxis* sp., *Carapus* sp. The absence of *Centriscus strigatus* and a large Syngnathid that were found in the Marecchia river deposit up to the 2.4 Ma climatic crisis, and the presence of *Bregmaceros albyi*, which has also been found in Mediterranean deposits up to and not beyond 2.2 Ma, have made it possible to determine the age of the Samoggia deposit as lying between the two above dates.

The ichthyofaunistic complex made up almost exclusively of living species is similar to those found in the other deposits in central-eastern Italy. This, as well as some sedimentological considerations, allows us to suggest that

	Winter temperature of surface waters				
	25°C- 20°C Tropical seas	20°C - 15°C Subtropical seas	15°C - 10°C Warm temperate seas	10°C - 5°C Cold temperate seas	5°C - 0°C Cold seas
Spratelloides gracilis	■				
Aluterus	■				
Cantherhines	■				
Chaetodon hoefleri	■				
Etrumeus teres	■	■			
Bregmaceros	■	■			
Lestidiops		■	■		
Ceratoscopelus maderensis		■	■		
Syngnathus acus	■	■	■		
Capros aper	■	■	■		
Lepidopus	■	■	■		
Cyclothone	■	■	■		
Diaphus	■	■	■		
Auxis	■	■	■		
Carapus	■	■	■		
Gadiculus		■	■	■	
Lobianchia dofleini		■	■	■	
Argyropelecus hemygymnus		■	■	■	
Lampanyctus pusillus	■	■	■	■	
Vinciguerria	■	■	■	■	
Xiphias gladius	■	■	■	■	
Arnoglossus laterna	■	■	■	■	
Scomber	■	■	■	■	
Solea	■	■	■	■	
Maurolicus muelleri	■	■	■	■	
Trachurus	■	■	■	■	
Engraulis	■	■	■	■	
Electrona	■	■	■	■	
Sarda	■	■	■	■	■
Micromesistius poutassou		■	■	■	■
Merluccius merluccius		■	■	■	■

Fig. 3 — Palaeoclimatic characters of taxa found in the Samoggia Torrent deposit.

there was a common genesis for all these deposits, which grew out of anoxic events on a regional and, most probably, a supraregional scale.

The Lower and Middle Pliocene ichthyofaunistic associations in central-eastern Italy (Samoggia Torrent, Marecchia river, Metauro river, Sforzacosta) are subtropical and thus indicate that the presentday biogeographical relationships between the Mediterranean ichthyofauna and the ichthyofauna of the adjacent Atlantic region were already well defined in the Lower and Middle Pliocene.

Lastly, the presence in the Italian Pliocene deposits of species with exclusively Indo-Pacific affinities that were already living in the Upper Miocene Mediterranean basin, is a point in favour of the hypothesis that during the salinity crisis areas with normal salinity remained in the eastern Mediterranean.

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